IOP Institute of Physics

Engineering Case Study – Nuclear Engineering

Institute of Physics response to a House of Commons Innovation, Universities, Science and Skills Committee Inquiry

A full list of the Institute's responses and submissions to consultations can be found at www.iop.org

14 March 2008

14 March 2008

Clerk to the Committee
Innovation, Universities, Science and Skills
Committee Office
House of Commons
7 Millbank
London SW1P 3JA

IOP Institute of Physics

Dear Sir/Madam

Engineering Case Study – Nuclear Engineering

The Institute of Physics (IOP) is a scientific membership organisation devoted to increasing the understanding and application of physics. It has an extensive worldwide membership and is a leading communicator of physics with all audiences from specialists through government to the general public. Its publishing company, IOP Publishing, is a world leader in scientific publishing and the electronic dissemination of physics.

The IOP welcomes the opportunity to respond to the House of Commons Innovation, Universities, Science and Skills Committee's Inquiry on nuclear engineering.

The attached annex highlights the key issues of concern to the IOP which have been linked to the specific questions raised.

If you need any further information on the points raised, please do not hesitate to contact me.

Yours faithfully

Professor Peter Main
Director, Education and Science

IOP Institute of Physics

Engineering Case Study – Nuclear Engineering

The UK's engineering capacity to build a new generation of nuclear power stations and carry out planned decommissioning of existing nuclear power stations:

The UK is facing a critical skills shortage in the nuclear technology sector. The energy portfolio, nuclear decommissioning, radioactive waste management and new nuclear build are very much in the nation's strategic interest, and this is a crucial time to ensure that the nuclear skills base is not eroded but built up to meet the long-term challenges of a possible new build programme. Even without new build, the entire nuclear industry employs over 18,000[1] graduates and skilled people, with ongoing recruitment required to fill vacancies, particularly for decommissioning. More detailed estimates of the numbers required to allow for new build were made in the Nuclear Task Force's report, *An Essential Programme to Underpin Government Policy on Nuclear Power*[2], 2003. This report estimated that 355 scientists and engineers were required, including 122 engineers. The engineering sub-groups, in order of size, were: chemical engineers, remote inspection, safety risk assessment, thermal hydraulics, and control and instrumentation.

All of this would be daunting enough if the skills shortages were confined to the nuclear sector, but the UK has a general shortage of science, technology, engineering and mathematics (STEM) skilled graduates. The energy supply sector is undergoing change and rapid expansion in many other fields that also require graduate and technical expertise, examples include clean-coal and renewables technologies. It is essential to see the need for nuclear engineers within the comprehensive need of all energy supplies as development and change occurs in response to climate change.

Currently, many experienced nuclear engineers in the UK are over the age of 50 and thus likely to be retiring within the next decade. All of the engineers involved in the original planning and building of the UK's nuclear power stations (the first of which opened in 1956) have already retired. There is also a possibility that expertise will be lost rather than passed on, particularly given the high proportion of freelancers in the sector. Therefore, there is a need to ensure that a new generation of nuclear engineers are trained while ensuring that existing expertise is used efficiently and properly incentivised.

A survey of Nuclear Employers undertaken by Cogent in 2005[3] found that:
"*The SET workforce has a more ageing profile than the overall industry. 11% are due to retire over the next 10 years, but this could rise as high as 20% if early retirements at age 60 occur. Certain areas were found to have an older workforce, e.g. 44% of process & machine operatives are aged over 45. While overall demand for this group may be declining this is outstripped by the rate of retirements. Nuclear heat generation has an ageing profile with 18% due to retire over the next 10 years; however this could rise up to 33% if early retirements occur*."

[1] Nuclear Power: Keeping the Option Open, The Institute of Physics; June 2003; www.iop.org/activity/policy/Events/Seminars/file_3514.pdf
[2] *An Essential Programme to Underpin Government Policy on Nuclear Power*, Nuclear Task Force, 2003
[3] www.cogent-ssc.com/research/Publications/Archived_Publications/Nuclear_Employers_Survey.pdf

Furthermore, the Energy Research Partnership (ERP)[4] found in its investigation into high-level skills shortages in the energy sector that, "*The problem is only at its early stages – without intervention this situation is anticipated to worsen to a severe shortage, particularly when the extent of energy innovation and infrastructure replacement that is required is taken into account*."[5]

The National Skills Academy for Nuclear (NSAN)[6], launched earlier this year, estimated that 1500 skilled people need to be replaced each year, with an additional 11,500 over the next 20 years to complete the task of decommissioning, and 6500 in other civil/defence sectors, which includes new build[7]. New build projects will face competition for staff from other areas of the nuclear technology sector and beyond.

Hence, there is an urgent need to maintain and develop a nuclear skills base, particularly in the core sciences (especially physics), engineering, materials science, project management, and technician level skills. By focusing this Inquiry on 'nuclear engineers' it is possible to obtain a misleading impression, both in terms of training and employment. It is important to note that significant areas of nuclear power technology (its full life-cycle including waste-handling and decommissioning) are underpinned by physics, such as reactor technology, nuclear data measurement and evaluation, safety, criticality studies, and materials properties.

The NSAN's remit covers skills at school, in vocational qualifications and further education, up to and including foundation degrees. Its responsibility is focussed on young people at the beginning of the pipeline, but does not extend into higher education. The NSAN has a critical role to play in developing a standardised and coordinated approach to education, training and skills development in the nuclear sector. The government and Cogent need to support the academy and encourage more research centres to be developed in order to ensure that the skills base is buoyant, fully trained and equipped to meet the challenges that the nuclear sector will face.

The nuclear industry also currently needs well-trained graduates in physics, chemistry, materials science and mechanical and control engineering who can obtain specialist industrial skills in reactor technology through in-house training and university postgraduate courses. It is therefore important to the sector that sufficient students are recruited on engineering and physical science undergraduate programmes whether or not they are 'nuclear' based.

The UK's nuclear engineering capacity is also dependent on the training in ethical issues of its science and engineering students. Nuclear engineers regularly face ethical issues in preparing safety cases, reporting scientific findings with safety-case significance, and dealing with the regulator in a commercial environment. Engineers who have acquired a sound ethical awareness in their education will be better able to handle the pressures associated with these activities. A nuclear-oriented course which puts ethics at the centre of professional practice is also more likely to appeal to young people considering careers in the nuclear industry.

In the last few years there has been an increase in university education and research activity in the nuclear area, which some believe could be a platform for the UK to provide the necessary training for a new generation of nuclear engineers, in order to ease concerns about the skills base.

[4] www.energyresearchpartnership.org.uk/erp.php?sid=1
[5] Investigation into high-level skills shortages in the energy sector, Energy Research Partnership
[6] www.nuclear.nsacademy.co.uk/
[7] www.cogent-ssc.com/cogent_family/NSAN.php

Undergraduate degrees in physics can contain a good range of nuclear physics, through taught courses, laboratory and project work. The IOP's *Core of Physics*, setting out the requirements for an accredited physics degree, includes a set of requirements for nuclear physics coverage[8]. Physics graduates can move easily across into nuclear engineering areas, and are often considered to be the most versatile graduates. We understand that there are several new nuclear-related undergraduate programmes in the pipeline, planned to be introduced at Lancaster University, Imperial College London and the University of Surrey.

Until recently there was a significant period of time when the only UK graduate course for nuclear power technology was the MSc Physics and Technology of Nuclear Reactors based in the School of Physics and Astronomy at the University of Birmingham[9]. This course provides the necessary background, both in breadth and in depth, for anyone wishing to enter the nuclear industry (in fact, Birmingham has a partnering agreement with the UK nuclear industry for the course). More recently, there are a few other universities, such as Lancaster, Liverpool and Manchester that offer relevant MSc courses. Based at the University of Manchester, the Dalton Nuclear Institute[10] regularly offers MSc project placements within its nuclear research groups, for a three-month duration, which provide an excellent opportunity to get hands-on experience of undertaking research. The University of Surrey offers similar opportunities on its MSc in Radiation and Environmental Protection[11], which has been running for 30 years with strong support from AWE and others, where graduates are eagerly sought. (Current support for MSc placements from industry is generally offered at the expense of companies, since supplementary projects are generated for placement students, which cannot be employed on actual fee-earning industrial projects because of time, commercial and confidentiality issues.)

Furthermore, both the School of Physics and Astronomy at the University of Birmingham and the Dalton Nuclear Institute are part of the Nuclear Technology Education Consortium (NTEC[12]). This is one of several initiatives funded by the EPSRC to address the immediate skills shortage in the nuclear industry. The NTEC comprises 11 institutions offering postgraduate education in nuclear science and technology for graduates from a general science background. The portfolio of courses has been designed through close consultation with the industry and it covers both reactor technology and nuclear decommissioning areas. The delivery format makes it ideal for use by those already employed in the industry either as a route to a postgraduate award or for CPD purposes. The core modules are also offered in distance-learning format. The number of new UK graduates coming through this programme is limited only by EPSRC-funding (limited to 10 studentships per year, funding only secure until 2008/09). Almost all students coming through this programme have either gone into the nuclear industry or into academic research. More students apply to the NTEC than there are places funded, and the programme has the capacity to expand considerably if funding for fees and stipends were made available. When the Consort reactor closes[13], the NTEC is the only place in the UK that offers experimental reactor physics training on a working reactor (the TRIGA reactor in Vienna).

[8] The Physics Degree; www.iop.org
[9] www.ph.bham.ac.uk/prospective/postgrad/pgptnr.htm
[10] www.dalton.manchester.ac.uk
[11] www.ph.surrey.ac.uk/msc/rep
[12] www.ntec.ac.uk/
[13] Strategic decision of Imperial College London to close to commercial operations by the end of March 08 and shut down within a few months, although this is being kept under review.

The Nuclear Engineering Doctorate is a programme run by a national consortium of six universities[14]. The scope includes reactor technology, materials and safety systems and is marketed to students from the various backgrounds, such as: aerospace; chemical; chemistry; civil; computer science; materials; mechanical; and physics. This confirms the point that the skills needed are much broader than just 'nuclear engineering'. The programme provides outstanding students with intensive, broadly-based training in collaboration with industrial companies to prepare them for senior roles in the nuclear industry. Few 'research engineers' entering this programme have a standard engineering background. A good fraction start off as physicists and either convert on the NTEC or Birmingham MSc, or join the Nuclear EngD programme directly.

The UK's supply of nuclear engineers is dependent on a healthy nuclear physics research community, which provides a large part of the nuclear training and education at undergraduate, masters and doctorate-level. The UK currently has nine university based nuclear physics research groups at Birmingham, Brighton, Edinburgh, Glasgow, Liverpool, Manchester, Paisley (i.e. University of the West of Scotland), Surrey, and York. Academic nuclear physics has had limited support from the research councils and has had no direct involvement in any of the major facilities needed for research in this area. This situation compares poorly with other European countries. Moving the funding of nuclear physics to the STFC provides an opportunity to strengthen the academic base, developing a long-term strategy for the subject. This is important in terms of training at postgraduate level and attracting undergraduates to this area.

Research programmes such as 'Keeping the Nuclear Option Open'[15] and 'Sustainability Assessment of Nuclear Power'[16], funded by the EPSRC, are helping universities to maintain their research groups and recruit new staff which is an important part of addressing the UK's skills issue.

The aforementioned progress being made to address the skills issues is very encouraging, coupled with the planned establishment of the National Nuclear Laboratory, based around the British Technology Centre at Sellafield. But it is vital that this progress continues and gathers momentum, as it will make an important contribution to retaining key nuclear skills in the UK. However, the government needs to monitor the situation, and must encourage more of the same, given the scale of the skills challenge and the fact that many of the key people are close to retirement just as the industry could be embarking on a new build programme.

Before its reorganisation in 2005, BNFL provided a strategic view on UK skills and expertise, responding to any at-risk areas directly by establishing university research alliances. Examples included Radiochemistry (Manchester), Waste Immobilisation (Sheffield: Immobilisation Science Laboratory), Particle and Colloid Science (Leeds), and Materials Performance (UMIST, now Manchester). A small group of BNFL representatives made the case to the EPSRC for the need to support education and research initiatives in well-defined nuclear technology areas. The UK has now lost this strategic thought and leadership, as well as the source of funding for industrial research. Nexia Solutions, BNFL's own R&D organisation, has also been left in a perilous state.

[14] www.manchester.ac.uk/engd
[15] www.epsrc.ac.uk/ResearchFunding/Programmes/Energy/Funding/TSEC/KeepingTheNuclearOptionOpen.htm
[16] http://gow.epsrc.ac.uk/ViewGrant.aspx?GrantRef=EP/F001444/1

The value in training a new generation of nuclear engineers versus bringing expertise in from elsewhere:

The nuclear skills base may need to be supplemented by the international supply chain, but the government's focus should be on a core UK workforce, for reasons of cost, sustainability, and national energy security.

It would be wrong to assume that there is an international pool of staff from which the UK could easily recruit; rather, we are potentially behind the game and will have to compete even to retain scientists and engineers trained in the UK from working overseas. There will be intense international competition for skills. For example, China, Finland, France and India are all planning new build, and it has been suggested that Russia alone is planning 40 new nuclear power stations; other countries are already building up their own staffing accordingly. Companies such as Westinghouse in the US and Areva in France are seeking to recruit very large numbers of nuclear trained personnel. Westinghouse recruited over 800 people globally in 2007 and expect to take on well over 1000 in 2008. The French INSTN has taken a major step forward by organising the 'International School in Nuclear Engineering: Doctoral-level Courses in Advanced Nuclear Science'[17], launched in 2007 to recruit and retain highly qualified staff. Furthermore, the UK's position in the international competition for skills will be exacerbated by the attraction of working for a company which designs as well as builds the reactors, rather than a subsidiary which helps build or decommission them.

In response, it is encouraging to note that the Dalton Nuclear Institute plans to establish a new Centre for Nuclear Energy Technology (C-NET)[18], which will aim to develop professionals with the skills to work in the global nuclear industry and will provide access to high-quality, independent academic research.

The ERP found during its private sector interviews that all employers were recruiting abroad for skilled roles. Furthermore, they found that:

"In four of these [companies] this is a business strategy due to the global nature of the business, in nine it was due to a lack of available skills in the UK. In three of these companies this was a recent (up to three years ago) move due to inability to fill roles in the UK. This was also the experience of two companies in their research involvement; two companies stated that they look abroad due to a shortage in a particular niche area, an example given being boiler engineering."

"The Henley report ... concludes that the best UK graduates are probably broadly comparable globally, although it notes the high quality of those engineering graduates from overseas universities that UK firms do encounter'. However,…this is so far not seen as significantly problematic for retention, and indeed one company recruits a significant number of non-home students and believes this is a sustainable, reliable source of very skilled labour."

It is already certain that the design of any new-build power station will be international, given that all four designs submitted for consideration (AP1000[19], EPR[20], ESBWR[21] and Advanced Candu[22]) are owned by non-UK companies. The

[17] www-instn.cea.fr/rubrique.php3?id_rubrique=176
[18] www.manchester.ac.uk/aboutus/news/display/index.htm?id=132502
[19] Westinghouse: http://ap1000.westinghousenuclear.com/index.html
[20] www.edfenergy.com/html/showPage.do?name=edfenergy.media.news.item.til&cmsPage=/opencms/export/www.edfenergy.com/media/news/20080110.html
[21] GE Energy: www.gepower.com/prod_serv/products/nuclear_energy/en/new_reactors/esbwr.htm
[22] www.aecl.ca

UK's nuclear industry will need to be an 'intelligent' owner of the plant once it has been completed, which will require a body of appropriately qualified staff. Even for a standard international reactor design, continuous demonstration that the plant is meeting all appropriate UK safety and environmental requirements requires detailed knowledge both of the plant itself and of the UK regulatory regimes.

It is essential to exercise skills in areas where the UK is recognised as a world leader, but also necessary to build skills in areas new to the UK. Such a skills base could be fundamental in the future for providing potential licensing and subsequent reactor operating activities within the UK for new reactor types.

As well as international competition for skills, there is competition from other sectors within the UK for the skills required by the nuclear industry. In seeking to ensure a 'critical mass' of students are recruited to various programmes in US Universities, the Nuclear Engineering Department Heads Organization (NEDHO) recommended that nuclear engineering departments in universities should "…diversify their activities while at the same time continuing to offer nuclear engineering curricula and maintaining their core competencies in nuclear power"[23], in order that courses might survive in the face of declining recruitment at that time. It is not surprising that the broad scope of courses has led to graduates looking beyond the nuclear industry for employment.

Competition for skills is also found, for example, in the application of nuclear techniques for diagnosis and treatment in medicine. In the study of materials, neutron scattering techniques – whether based on reactors or spallation sources – requires staff with a strong understanding of nuclear methods and modelling. Defence and homeland security also call upon the same recruitment pool and there is, finally, the ongoing experience that the financial world finds the skills of nuclear trained students attractive – and the students find the rewards in the financial world attractive too.

The role that engineers will play in shaping the UK's nuclear future and whether nuclear power proves to be economical viable:

The nuclear industry currently plays a key role in the UK economy, employing 50,000 directly and supporting many additional jobs. A new build programme will offer opportunities to maintain and grow this work force, while keeping alive the knowledge and expertise that has been built up.

The UK government has concluded that nuclear energy has a part to play in the UK's energy mix and it is clear that a range of other countries are taking similar decisions. In a world where there is increasing competition for dwindling fossil fuel resources and pressure to reduce carbon dioxide emissions, the nuclear technologist has a significant role to play in ensuing that a viable, convenient and affordable source of electricity remains available to the UK population.

[23] *Manpower Supply and Demand in the Nuclear Industry*, Nuclear Engineering Department Heads Organization (NEDHO), 1999
www-ners.engin.umich.edu/NEDHO/publications/manpower_report/Manpower_report2-17.pdf

A brief summary of the role of engineers and scientists in the UK's nuclear future is as follows:

- Safety, both in (i) the study of safety related issues such as loss-of-coolant accidents (LOCA) or severe reactor accidents, and (ii) case preparation and management, which demands intimate knowledge of facility design.
- Operation of the plant in the most economic, yet safe manner over the longest possible time.
- Life extension assessment and reactor plant evolution to meet future requirements of licensing and operational demands.
- Nuclear data measurement and evaluation, required for understanding of newer materials and concepts.
- Participation in the international programmes of reactor development, such as the Global Nuclear Energy Partnership (GNEP[24]), in order to maintain skills and expertise and be prepared to benefit from future developments.
- Materials science of nuclear fuels and other materials, in order to understand the way that these materials behave under longer burn-up and higher irradiation reactor conditions.
- Waste issues such as fuel cycle chemistry, partitioning and transmutation, in order to reduce the burden on waste disposal; and associated technologies such as accelerator driven systems (ADS).
- Decommissioning.
- Future concepts such as nuclear-generated hydrogen economy, as there will be a need to move to an electricity-based energy economy, which will need substantial change in transport and heating.
- Multi-scale modelling and simulation, which underpins most of the topics above and also demands significant computing skills.

The overlap between nuclear engineers in the power sector and the military:

Nuclear power and nuclear weapons share a significant number of fields of interest whether from the experimental or modelling aspects. There is a significant overlap in the skills requirements of the two areas, with traffic of expertise between them.

It is clear that the various companies involved in the UK naval reactor programme are all too aware of the potential for new build to compete with their recruitment needs.

[24] www.gnep.energy.gov

The Institute of Physics is a scientific membership organisation devoted to increasing the understanding and application of physics. It has an extensive worldwide membership and is a leading communicator of physics with all audiences from specialists through government to the general public. Its publishing company, IOP Publishing, is a world leader in scientific publishing and the electronic dissemination of physics

IOP Institute of Physics

76 Portland Place
London W1B 1NT

Tel: +44 (0) 20 7470 4800
Fax: +44 (0) 20 7470 4848
Email: physics@iop.org
Website: www.iop.org
Registered Charity No. 293851